Laser-induced Single Event Transients at High Temperatures for the LM139J Operational Amplifier

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I. Introduction

Pulsed-laser is a less expensive testing method to examine SEEs in linear bipolar circuits relative to heavy ion testing. Since electronic components in space often operate at a wide range of temperatures, it is necessary to study radiation effects such as SETs at elevated temperatures. The purpose of this experiment is to observe the effects of temperature on laser-induced SETs for the LM139 operational amplifier.

II. Device Description

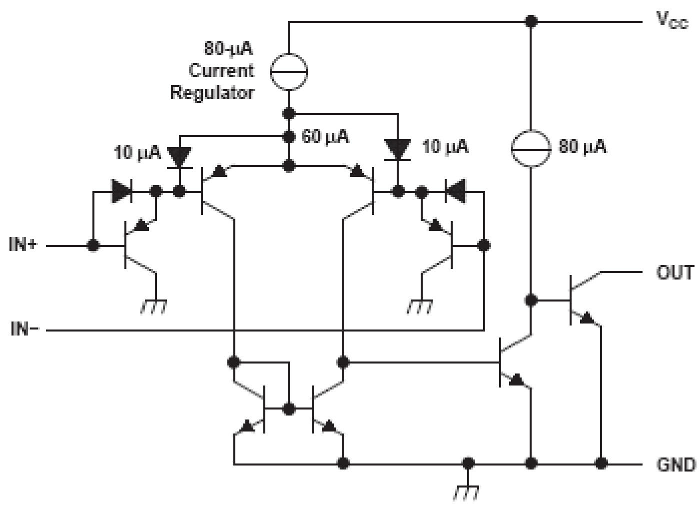
The device information is given in Table 1. The device specifications are shown in Table 2. Figure 1 shows the detailed circuit diagram.

Table 1. Device description.

Part Number	LM139J 5B-S
LDC	0535F
Manufacturer	Texas Instrument
Package	DIP 14
Function	Voltage comparator
Technology	Linear bipolar
Previous Testing	Part previously tested by laser irradiation at room temperature [1]

Table 2. Device specifications.

Parameter	Condition	Min	Max	Unit
Operating temperature (T_A)		-55	125	^oC
Output voltage (V_O)			36	V
Output current (I_O)			20	mA
Input bias current (I_B)	$V_O = 1.4$ V		-300	nA
Input offset voltage (V_{IO})	$V_{CC} = 5 – 30$ V, $V_O = 1.4$ V		9	mV



All current values shown are nominal.

Figure 1. Circuit schematic of the LM139J.

III. Test Facility

The testing was conducted at the Naval Research Laboratory with a YLF laser. The laser beam characteristics are listed in Table 3 below.

Table 3. Laser characteristics.

Wave Length	590 nm
1/e penetration depth	2 μm
Beam diameter	1.7 μm

IV. Test Setup and Bias Configurations

The test conditions are also listed below.

Testing Temperature: Room temperature, 50°C, 75°C, 100°C, and 120°C
Power supply (V_{cc}): $V_{cc} = 5$ V
Input voltage (V_{in}): (1) $V_{in+} = 0.1$ V, $V_{in-} = 0$ V
(2) $V_{in+} = 0$ V, $V_{in-} = 0.1$ V
Parameters of interest: Amplitude and width of SETs. The oscilloscope was preset to trigger at ~ 200 mV. The trigger voltage level was adjusted appropriately according to the transient levels observed during the experiment.

Test condition (1) produces a high output (5 V), with negative-going transients. Test condition (2) produces a low output (0 V), with positive-going transients. A block diagram of the test setup is shown in Figure 2. A power supply provides power and input voltages to the device. The oscilloscope is connected to the output to monitor the output voltage levels, and record any SETs above the threshold. The elevated temperature test setup requires a power supply, multimeter, thermal pad, and thermistor. The power supply outputs voltage to the thermal pad, which is attached to the device. The temperature increases as the voltage is increased. A multimeter measures the resistance of the device through a thermistor, which is also attached to the device. The resistance is converted into temperature by a program controlled by a laptop computer. The computer manages the amount of power applied to the device and the temperature of the device.

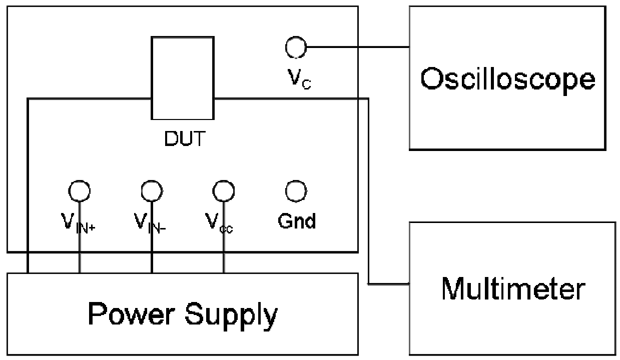


Figure 2. Block diagram of the test setup.

V. Results

The LM139 package contains 4 comparators. One device from the quad was chosen for the experiment. Different locations were scanned using the pulsed-laser. Transistors Q2, Q6, and Q8 were irradiated while the device was biased with high output. Transistors Q3 and Q7 were irradiated while the device was biased with low output. Figure 1 shows the SETs for Q6 from 27^{o}C to 100^{o}C with high output. Figure 2 shows the SETs for Q2 at 27^{o}C and 100^{o}C to better illustrate the pulse behavior at high temperature. Figure 3 shows the SETs for Q3 while the device was biased with high output. The waveforms shown are representative of pulse shapes from other transistors. The temperature effects on the pulse characteristics were similar for all irradiated transistors.

In some cases, notably for Q3, the number of SETs with larger amplitudes increases at elevated temperatures. In order to make distinct comparisons of the pulse shapes at different temperatures, the laser intensity was reduced so that the waveforms are approximately the same shape.

We observed that the SET pulse fall time (leading edge for high output and trailing edge for low output) increases with increasing temperature. The fall times connote the device response time, also characterized as the device slew rate. The slew rate is determined from the slope of the linear portion of the SET pulse's trailing edge. The slew rate decreases with increasing temperature for all irradiated transistors, and for both output conditions. A summary of the slew rate vs. temperature for various transistors is shown in Figure 6.

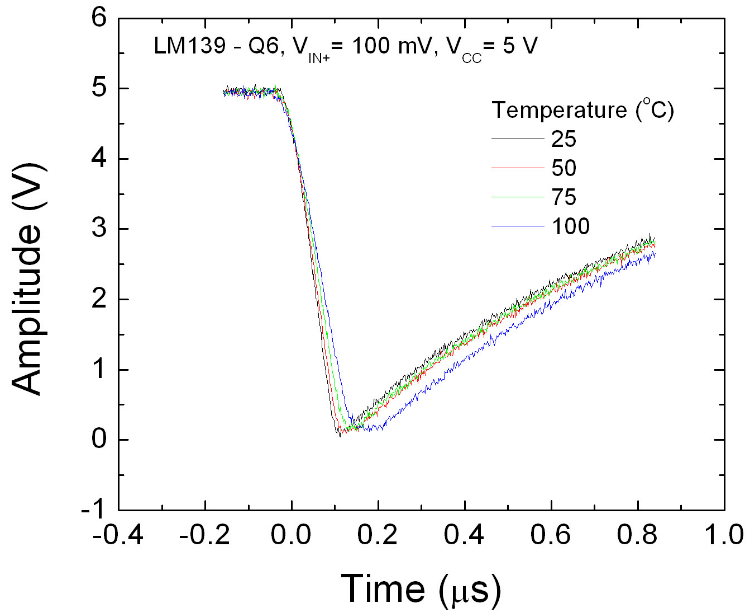


Figure 3. SETs at various temperatures for transistor Q6 of LM139 with high output.

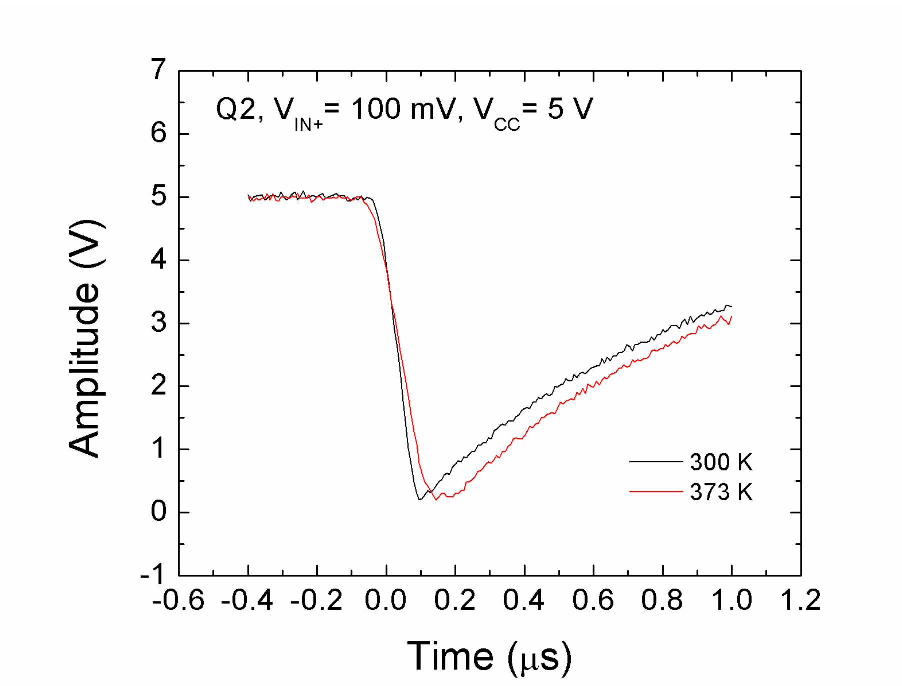


Figure 4. SETs at 27^{o}C and 100^{o}C for transistor Q2 of LM139 with high output.

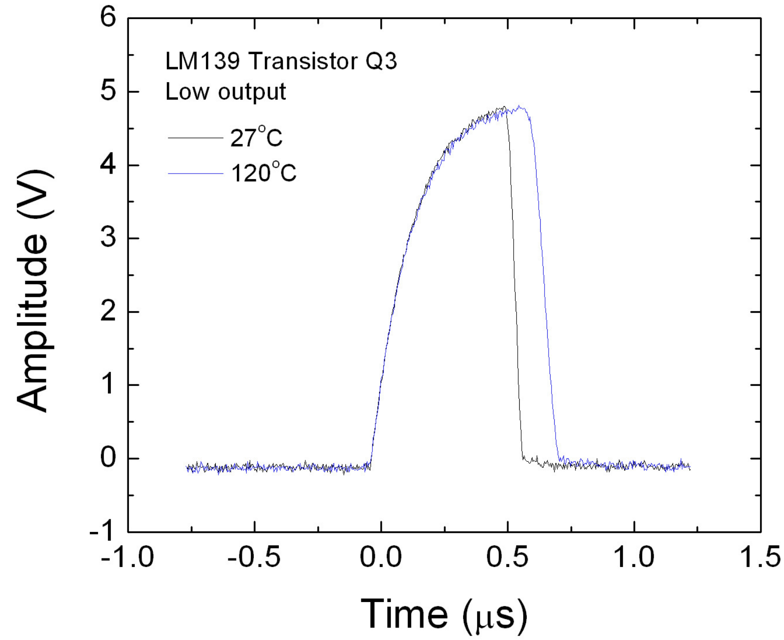


Figure 5. SETs at 27°C and 100°C for transistor Q3 of LM139 with low output.

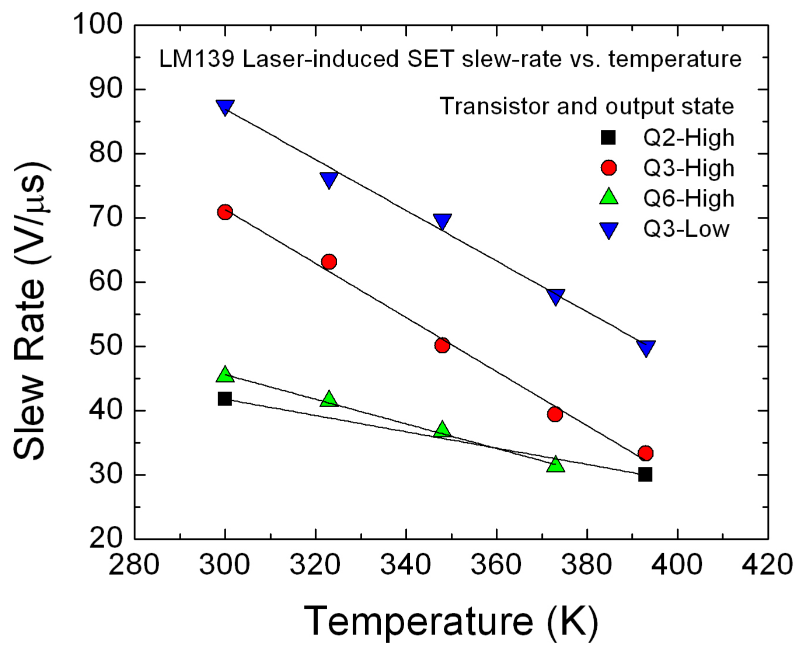


Figure 6. Slew rates vs. temperature for various transistors of the LM139 with high or low output.

VI. Conclusion

The primary temperature effect is the reduction in the comparator slew rate with increasing temperature. The trend is consistent for transistors in different stages of the comparator, and for both high and low output modes. The largest decrease was ~ 50 % for transistor Q3, in both output conditions. The degraded slew rate also implies that the recovery time from an SET increases at elevated temperatures. Its significance depends heavily on device application. Nevertheless the SET's temperature dependence should be considered for radiation hardness assurance designs.

VII. Reference

[1] M. Bernard et al., "Impact of total ionizing dose on the analog single event transient sensitivity of a linear bipolar integrated circuit," *IEEE Trans. Nucl. Sci.*, vol. 54, Dec. 2007, pp. 2534-2540.